Department of the Army
U.S. Army Corps of Engineers

Electrical & Mechanical Conference
Engineering Technology Transfer and Training Conference

June 2-4, 1998, Kansas City, Missouri

Emergency Electrical Power Systems
Testing -- Start up -- Documentation

by

George Scliffet -- Senior Sales Engineer
Kohler Company -- Generator Division
Kohler, Wisconsin

3/20/98

Emergency Electrical Power Systems

Testing -- Start up -- Documentation

George Scliffet -- Senior Sales Engineer
Kohler Company -- Kohler, Wisconsin
(920) 459 - 1730, FAX (920) 459-1781

Abstract:

This paper discusses the importance of **testing, start up,** and **documentation.** These items are very important elements that are required for the successful implementation, and long term reliability of the emergency electrical power system. The emergency electrical power system components are defined as the engine generator set(s), automatic transfer switch(s), paralleling switchgear, and associated auxiliary equipment.

Testing includes the manufacturers' prototype, production, factory system, and on site testing. This testing is done to assure that emergency electrical systems will perform to expectations when required. Quality and reliability programs are also important elements, and an integral part, of all testing and manufacturing processes. Optional witness testing permits the purchaser to review the tests as they are being conducted at the manufactures' facility prior to shipment.

Routine maintenance and operational testing comprise other essential elements that ensure long term reliability of the emergency electrical power systems.

Index:

Introduction:

While most specifications address testing, training, and documentation, most do not include adequate descriptions to assure that all products will be supplied with the same level of safety, quality, and long term reliability. Many specifications are based on older product technology, outdated standards, and proprietary manufacturers' specifications. These specifications do not focus on the performance that is required for a specific project. We will attempt to assist you in determining the optimal level of testing, training, and equipment documentation that is required to assure a reliable emergency electrical power system. This paper is not intended to be a guide line specification that can be directly incorporated into a contract document. Sufficient references are included in the Appendix. These provide the specification writer, and purchasing authority, the information required to obtain reliable, quality emergency electrical equipment.

Prototype Equipment Testing:

Prototype testing is an integral part of the quality assurance program. All major emergency power system equipment manufacturers conduct prototype testing.. Prototype testing includes potentially destructive tests that are necessary to verify design, and proper function of protective devices and safety features. Reliability tests are conducted to establish life expectancy. Specifying prototype and reliability testing, and the careful review of all vender documentation will assure the purchaser that the product he receives a proven product, that has been adequately tested. Prototype testing also assures that the equipment will perform to his expectations, and meets the requirements of established national standards.

Prototypes are built and tested so that component and assembly design can be established and documented. After all prototype performance tests have been passed, production models are built and tested. This testing is used to verify production tooling, manufacturing processes, and reliability. Generator sets, automatic transfer switches, and switchgear are put into production only after satisfying all of these requirements. Reliability, and conformance to an established quality management system is also assured by the manufacture being certified as an International Organization for Standardization (ISO-9000) facility.

The National Fire Protection Association, NFPA 110 Standard for Emergency and Standby Power Systems© is the major reference for this type of equipment. A Prototype Testing Certificate certifying that the generator set has been tested, and complies, with this standard should be specified. The NFPA-110 standard requires that; “The capability of the energy converter, with its controls and accessories, to survive with out damage from common and abnormal disturbances in actual load circuits shall be demonstrable by test on separate prototype models..” NFPA 110 addresses system performance, and includes the prime mover, generator, exciter and the voltage regulator. The NFPA-110 Standard also addresses automatic transfer switches, and their test criteria.

Additional prototye testing to the National Electrical Manufactures Association (NEMA) standards should be included to further assure product reliability, and performance. Underwriters' Laboratories© standard UL-1008 for automatic transfer switches, and UL-1558 for switchgear are other important references.

There is a new standard being drafted by Underwriters Laboratories©, UL-2200. This standard is currently in the review and comment stage, that will ultimately permit the UL listing of the complete generator set.

Engine Prototype Testing

Prototype testing is performed on each model engine to determine performance and durability of the entire engine, as well as specific engine components.

Performance tests are performed on prototype engines with the specific configuration and power rating that is offered for a given application. Testing is conducted, and the data is recorded, to conform to the requirements of the Society of Automotive Engineers SAE J1349, as well as ISO 3046. Additional testing has been performed in the past, as required, for DIN standards, British Standards, as well as U.S. Military, and NATO standards.

Performance testing includes the measurement of speed, load torque (measurements of speed and torque are used to determine engine horsepower capability). Tests for intake air flow, peak firing pressure, fuel volume per cycle, and fuel specific gravity are also completed. Various engine operating temperatures and pressures are also measured during performance testing.

In addition, engine development and reliability tests are performed to determine life characteristics of critical engine components, and to develop new material technologies. These tests help to establish a data base for determining projections of overall engine life, the mean time between failure (MTBF), for both minor and major failures. Tests are also defined by Military Standards, depending upon specific applications.

Tests are also performed which are application specific. These can include test done to measure cooling system performance, and engine radiated heat. Others include radiated noise, vibration levels, raw exhaust noise levels, exhaust emission levels, and the engine center of gravity, using standard, and application optional engine equipment.

Generator and Generator Set Prototye Testing

Tests of the generator temperature rise per NEMA MG1-22, 40 and 16.40 are conducted to establish the standby and prime ratings of the generator. Since temperature is the major factor affecting generator life, this testing permits the proper selection of the generator set for the application

Maximum power tests assure that the prime mover and the generator have sufficient capacity to operate within the required specifications. Generator sets are rated for a specific power output with prescribed fuel, ambient, and altitude conditions, and derating factors are provided for application at other conditions. Generator set rating guideline and standards are included in the Appendix.

Generator overload tests per NEMA MG1-22.41 are recommended. Steady state load testing establishes that the voltage regulation meets or exceeds established ANSI C84.1, and NEMA MG1-16.47.2. These tests verify compliance with steady-state speed control specifications. These tests assure that the generator will perform in a predictable manner, and that the voltage will remain at an acceptable level.

Load testing for one step full load, and staircase load testing verifies that transient speed and voltage control will meet or exceed a given specification. Transient load tests per NEMA MG1-16.48.2 verifies the transient voltage regulation, voltage dip, voltage overshoot, recovery voltage, and recovery time. All generator sets will experience a drop in voltage when a load is applied. The voltage recovery response that is required depends upon the load equipment being energized by the generator set.

Motor starting tests are conducted to evaluate the capabilities of the generator, exciter and voltage regulator system. These tests per NEMA MG1-16.48.5 and include one step load pickup of full rated load at 0.3 (lagging) power factor. When emergency systems also supply power to a motor driven load, the ability of the generator set to respond with a minimum of deviation from the rated voltage is very important. Excess voltage dip can cause control devices to drop out, and affect other equipment being supplied.

Three phase symmetrical and short-circuit test are conducted per IEEE 115 to meet NEMA-16.45 and 22.45. These tests demonstrate short circuit performance, mechanical integrity, ability to sustain short circuit current, and functioning of the generator circuit breaker to protect the generator. With proper coordination, only the circuit breaker closest to the fault will trip, and the balance of the emergency system will continue to provide power.

Harmonic analysis, voltage waveform deviation per NEMA MG1-22.42, and telephone influence factor per NEMA MG1-22.43, confirm that the generator set is producing clean voltage within acceptable limits.

Fuel consumption tests at 25%, 50%, 75% and 100% of rated load provide data on the cost of operation, and, more importantly, give information for the proper design of the fuel system.

Torsional analysis is used to verify absence of harmful Torsional effects at synchronous speeds. The speed is 1800 RPM for 60 HZ, 4 pole generator applications,
+/- 10% to allow for normal and abnormal operation.

Generator cooling test, and cooling airflow test verify the maximum operating ambient temperature, and confirm fan design criteria. These tests are used to establish the required airflow, and the maximum airflow restriction. This data is then used to specify the intake and exhaust louver sizes, or remote cooling system requirements..

Endurance testing is followed by inspection for failure and defects. A forensic analysis of any failed components is used to determine design, workmanship, or component problems. Endurance test programs are designed to subject the equipment to conditions that can be used to predict the long term performance, durability, and reliability, of the assembly.

Acoustical noise intensity and sound attenuation effect tests are conducted to determine how much sound is produced, at what frequencies, and from which part of the assembly. This data is then used to design sound reduction enclosures, and to permit proper site location of the equipment.

Other prototype information that is developed would include vibration analysis, control device operation features, safety, center of gravity calculations or measurement, starting capability, and a finite element analysis of the skid.. All of the prototype data that was determined by design and prototype testing is tabulated and provided on the manufacturer's data sheets.

Automatic Transfer Switch Prototype Testing

Automatic transfer switches (ATS) are subjected to their own prototype testing program. Underwriters Laboratories© standard UL-1008, NEMA ICS 1.109.05 and ANSI C37.90 are standards that would apply.

The automatic transfer switch must pass overload and endurance testing when enclosed per Tables 25.1, 25.2, 27.1, and 27.2 of UL-1008. Temperature rise test are conducted after the overload and endurance test. These tests confirm the ability of the transfer switch to carry the rated current within the allowable temperature limits. The limits are governed by the insulation in contact with current carrying parts.

Withstand current test per Paragraph 25 of UL-1008 for the specified amperes RMS symmetrical, at 480 volts, and X/R ratio of 6.6 are conducted as part of the prototype test program.

A dielectric test at 1960 volts, RMS, minimum is conducted after the withstand current test.

Switchgear Prototype Testing

Most manufacturers do not have a line of standard prototype tested switchgear. The switchgear is designed to meet the individual project specification requirements and is assembled from standard Underwriters Laboratories listed components. The switchgear is then production tested in accordance with UL-891, and the manufacturers' procedures. If the components are UL or UR labeled, and the assembly meets specified clearances, bending radius, and other requirements, the manufacture then may UL list and label the equipment.

Several manufacturers have developed and market standard prototype tested designs, which should be specified. The advantage to the specifier and purchaser, is that they are procuring a proven, fully tested, UL-1558 listed and labeled product. Since the prototype switchgear has been developed without the need to meet a project delivery schedule the manufacturer will incorporate many features that provide ease in assembly, installation, service, and increased long term reliability. The assembled prototype switchgear has been subjected to potentially destructive testing to assure that all components, including circuit breakers, conductive bus and structure will carry rated current, and withstand short circuit fault conditions. UL-1558 is more extensive, and includes UL-891. This standard is applicable to all 600 Volt or less air power switchgear.

These prototype, or design tests, are described in detail in the Institute of Electrical and Electronic Engineers, Inc., IEEE Std C37.20-1993, Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear in section 5.2.1 through 5.2.9. This testing consists of dielectric, continuous current, short-time current withstand, mechanical endurance, flame-resistance, rod entry, paint qualification, and rain test for outdoor LV switchgear.

UL-1558 Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear requirements are intended to supplement and are be used in conjunction with ANSI Standards. The Standard for Metal-Enclosed Low Voltage Power Circuit Breaker Switchgear, is ANSI C37.20.1. The Standard for Conformance Testing of Metal-Enclosed-Low-Voltage AC power Circuit Breaker Switchgear Assemblies, is ANSI C37.51. Therefore by meeting UL-1558 the manufacture has also complied with the ANSI Standards. UL-1558 does not directly address testing except for the field testing of Ground - Fault Protection of Equipment.

Standard products minimize the time to manufacture, and improves the quality of the product.. The submittal process is streamlined, and more detailed documentation is provided with standard switchgear. Prototype design testing eliminates on site problems. The design has been evaluated for any failed components to determine any design, workmanship or component problems. Prototype and reliability switchgear testing subject the equipment to conditions that can be used to predict the long term durability, performance, and reliability of the assembly. Prototype tested certification is available, and should be specified to be supplied, with the product submittal.

Equipment Production Testing:

Generator Standard Production Testing

Each alternator is tested per MIL-STD-705 before it is assembled into a generator set. These tests include winding resistance (401.1a), insulation resistance of all windings (301.1b), and high potential test on all windings (302.1a). The air gap is measured, the voltage regulator is checked for proper operation, and the exciter field current and voltage balance are verified.

Engine Standard Production Testing

Each engine undergoes a complete tests at the end of the production line to verify engine performance. These tests are conducted on a dynamometer for up to 45 minutes to confirm engine power at rated speed. Engines are also treated with a special solution and visually checked for any leaks. Coolant temperatures are check to assure that they remain within the defined parameters. These tests are conducted in accordance with SAE J1349 and ISO 3046 standards. Test reports are shipped with each engine.

Generator Set Production Testing

In production, standby and prime rated generator sets are manufactured to the stringent standards established by the prototype program. Every generator set is fully tested as an assembly prior to leaving the factory. Production testing includes the following testing conducted in accordance with MIL-STD-705 as referenced below, for each generator set:

Stator and exciter winding resistance (401.1a), insulation resistance (301.1b), and high potential tests (301.1b) are conducted on all generators. Surge transient test are conducted on stators for generators 180 kW and larger. The air gap is measured, the voltage regulator is checked for proper operation, and the exciter field current and voltage balance are verified on all generators over 300 kW before assembly into the generator set. Continuity and balance tests are conducted on all rotors. One step, full load pickup tests, are conducted to verify that the performance of each generator, regulator, and governor meets the published specifications.

Regulation and stability of voltage and frequency are tested and verified at 25%, 50%, 75%, full rated, and maximum load. Voltage, amperage, frequency and power output ratings are verified by a 30 minute full load test.

The proper operation of all controller logic circuitry, prealarm warnings, and shutdown functions are tested and verified. Generator sets ordered with switchgear are also tested as a complete system at full load with their accompanying switchgear and transfer switches.

Any defect or variation from specifications that is discovered during testing is corrected and retested prior to approval for shipment to the customer. Certified factory test reports are available and should be requested.

Additional testing at the customer's request can be conducted. These optional tests include customized load testing for a specific application, witness testing, and a broad range of MIL-STD-705 tests.

Automatic Transfer Switch Production Testing

After assembly, the complete automatic transfer switch is tested to assure proper operation of the individual components, and correct overall sequence of operation. The ATS is tested to assure that the operating transfer time, voltage, frequency and time delay settings are in compliance with the specification requirements. Inspection verifies that the installed options match the order. Paint is checked to verify that it meets quality standards, leads and harnesses are verified for properly installation, and the plug and pin insertion is checked. Communication, and circuit boards are tested after manufacture, and again with the ATS assembly, to assure proper operation.

The complete automatic transfer switch is subjected to a dielectric strength test per NEMA Standard ICS 1.109.21.

Switchgear Production Testing

Switchgear production testing includes both static and operational tests.. A minimum sequence would include a visual inspection for completeness, workmanship and dimensional accuracy, plus static, and operational test. Static testing verifies that all wiring is correct per the drawings. Operational tests would include sequence, timing and relay setting, and verification that the controls will operate in the proper manner.

After assembly the automatic paralleling switchgear is inspected and tested prior to shipment per IEEE Std C37.20-1993 as detailed in section 5.3 Production test. This test sequence requires the following:

* Insulation dielectric test (hi-pot) of the bus system to determine the integrity of the power system.
* Verification of circuit continuity and wiring for both the control and power equipment.
* Operation of all drawout circuit breakers, and protective relays.
* Verification of the proper operation of all meters, relays, and control circuits.
* Verification that the equipment arrangements, types, ratings, and operational sequence confirm to the drawings and specifications.

* Verification of polarity and phasing of the switchgear bus, instrument, and control circuits.

The consultant engineer should be notified two (2) weeks prior to the factory test, and have the option of witnessing the test. After the test copies of the certified factory test report are forwarded to the engineer for his records.

Optional Testing:

In addition to standard production tests, optional special testing of the generator set and generator is available. These tests are conducted in accordance with MIL-STD-705C. The special tests are conducted after the standard production testing has been completed. Typical tests are as follows:

Generator Set Optional Test

301.1C	Insulation Resistance Test
302.1B	High Potential Test
401.1B	Winding Resistance Test
503.1C	Start and Stop Test
503.2C	Start and Stop Test (Remote)
505.1B	Overspeed Test (Set)
505.2B	Overspeed Protective Device Test
506.1B	Under-speed Protective Test
507.1D	Phase Sequence Test (Rotation)
508.1D	Phase Balance Test (Voltage)
509.1B	Circulating Current Test
511.1D	Regulator Range Test
511.2C	Frequency Adjustment Range Test
515.1B	Low Oil Pressure Protective Device
515.2B	Over Temperature Protective Device
601.1D	Voltage Waveform Test (Oscillographic)
601.4B	Voltage Waveform Test (Harmonic Analysis)
601.5	Voltage Waveform Test (Deviation Factor)
608.1B	Voltage and Frequency Transient Response
610.1B	Voltage and Frequency Droop Test
614.1B	Voltage and Frequency Regulation Test
619.2C	Voltage Dip and Rise for Rated Load Test
620.1B	Voltage Unbalance with Unbalanced Load (Line-to-Neutral Load)
620.2B	Voltage Unbalance with Unbalanced Load (Line-to-Line Load)
620.4B	Voltage Unbalance Test (Three Wire, Single Phase)
640.1D	Maximum Power Test @ 1.0 P.F.
670.1B	Fuel Consumption Test @ 25%, 50%, 75% and 100% Load

680.1C	Temperature Rise Test
690.1D	Endurance test @ either 0.8 or 1.0 P.F

Generator Optional Testing

410.1	Open Circuit Saturation Curve
411.1	Synchronous Impedance Curve -- S.C. Saturation Curve
412.1	Zero Power Factor Saturation Curve
413.1	Rated Load Current Saturation Curve
415.0	Summation of Losses.
420.1	Short Circuit Ratio
421.1	Direct-Axis Synchronous Reactance (Xd)
422.1	Negative Sequence Reactance (X2)
423.1	Zero-Sequence Reactance (Xo)
425.1	Direct-Axis Transient Reactance (X'd)
426.1	Direct-Axis Subtransient Reactance (X"d)
427.1	Direct Axis Transient Short Circuit Time Constant (T'd)
430.1	Direct-Axis Transient Open Circuit Time Constant (T'do)
432.1	Short Circuit Time Constant of Armature Windings (T'a)
505.1	Overspeed (Generator)
511.1	Voltage Regulator Range
601.1	Voltage Waveform (Oscillographic)
601.4	Voltage Waveform (Harmonic Analysis)
601.5	Voltage Waveform (Deviation Factor) in conjunction with 601.4
611.1	Inherent Voltage Droop (Generator Only)
615.1	Inherent Voltage Regulation (Generator Only)
620.1	Voltage Unbalance with Unbalanced Load (L-N Load)
620.2	Voltage Unbalance with Unbalanced Load (L-L Load)
625.1	Short Circuit Test (Mechanical Strength) 3 phase -- 7000 A Max.
680.1	Heat Run

These tests provide specific generator, or generator set testing and documentation. The costs of test vary and can add considerably to the cost of the generator set. For a recent set of tests completed on a 2000 kW, 4160 Volt generator set, the cost of the optional specified tests exceed $12,000.00. For this example, all test values essentially duplicated the earlier prototype data.

All optional tests require that the generator set(s) be set up in a test cell(s) with the proper certified recording equipment. The customer is provided with all of the testing documentation. Optional testing can be justified by the added security of verifying that specific generator set or equipment meets the specified criteria. Optional testing is most commonly seen on government projects with open bidding, and ultra critical emergency power systems.

Factory System Testing:

Factory system testing is the next level of performance testing. The major components comprising the emergency power system are tested together. The generator set(s), automatic transfer switch(s) and automatic paralleling switchgear are tested together as an interconnected system, under load. System testing is conducted at the generator set manufacturer's facility as a complete system.

This procedure assures that all equipment will perform as specified and designed. The system dynamics of the governor, voltage regulator, control devices, and communications all interact and are tested as a system to eliminate shared responsibility, and on site start up problems.

Testing with representative generator sets or generator sets using governor controls and voltage regulator equipment not installed and shipped with the switchgear is not an acceptable alternative.

The functional test includes a load test to demonstrate that the engines, and generators will share load when the generators are operating in parallel. During system testing the control sequence of operation is verified, and all modes of operation are tested. Load shedding controls, and engine management (fuel economizing) systems, are tested by adding and reducing the system load.

The manufacture should be prepared to demonstrate that the factory test facility is equipped with the required resistive and reactive load banks, fuel system, recording equipment, and all necessary sound and safety equipment. The facility should comply with all OSHA safety requirements, and follow an established safety program.

Kohler Company® has invested in a 6,500 square foot facility for system testing. The facility can accommodate three (3) generator sets rated up to 2000 kW in parallel, with switchgear for system testing.. Permanently installed resistive and reactive load banks, and transformers permit testing both domestic (60 HZ) and export (50 HZ) systems. Installed transformers are used through 6600 Volts and portable transformers are used for higher ratings. Controls for automatic load sequencing and data logging of voltage, current, frequency, wattage, and power factor are installed. Engine and generator pressures, temperatures, fuel usage, cooling, and electrical information is recorded with both certified chart recorders, and on personal computers that provide the customer with a complete testing history.

On Site Equipment Testing:

Start Up of Equipment, and Testing

After the equipment has been installed, it should be started up and tested at the site to assure that all equipment will function as specified. Site testing verifies correct connection, absence of any transportation damage, and proper operation under actual site conditions. Systems with switchgear require a field dielectric test per IEEE Std C37.20.1-1993, Section 5.5 before the equipment is placed into service.

The National Electrical Code® Article 700-4 (Emergency Systems), and 701-5 (Legally Required Standby Systems) requires that "The authority having jurisdiction shall conduct or witness a test of the complete system upon installation and periodically afterwards"

The equipment manufacturer should include in his quotation the cost of providing a qualified start up technician(s). These technician(s) assist the local system distributor, and the installing contractor, in the commissioning, and performing the on-site test of the equipment.

The system manufacture should submit the on-site test procedure to the consultant for review and approval, prior to the actual testing. Included in the data submitted there should be blank test forms to be used for recording the test data.

Sufficient building load or load banks equal to a minimum of 40% of the generator set capacity must be available to permit system testing. A load bank is also required, equal to at least 40% of the generator set capacity, for all utility parallel applications to allow the technician to set the load controls.

More generator sets are now being utilized to reduce electrical energy cost, in addition to emergency standby applications. Thus, more systems are being paralleled with the electrical utility grid. Utility paralleling requires additional loading and VAR controls, and finite protective relaying. The inclusion of short circuit studies, relay coordination studies, relay settings, and on site testing to meet the utility requirements are often added to the manufacture' responsibility. Many utility companies require that the testing and demonstration of protective relay operation be witnessed by their personnel.

System control and data acquisition (SCADA) systems have become more common and also increase the complexity of on site power systems. Proving the SCADA system is another reason that factory system testing should be conducted.

Upon completion and acceptance of the system testing, the system manufacture should furnish a report for the record of all data, device settings, and readings.

Routine Maintenance, Operation, and Testing

NFPA-110 requires routine maintenance and operational testing to assure the continuing reliability, and integrity, of the emergency and standby power system (EPSS). This routine maintenance and testing program (RMOT) is specified as being based on the manufacturer's recommendation, instruction manuals, the minimum as specified in Chapter 6, and the authority having jurisdiction. This testing program addresses the engine generator set, the automatic transfer switch, the line circuit breaker, and starting battery system. A written schedule for the routine maintenance testing and specific intervals are specified. NFPA-110 provides RMOT sample logs, and suggested maintenance schedules.

The National Electrical Code®, NFPA 70, requires periodic testing, battery system maintenance, written records, and testing under load, of all emergency power systems. Optional standby systems do not have a testing requirement, but prudent firms would also test these systems to assure proper operation.

Testing should always be done with adequate load to prevent *wet* stacking of diesel engine driven generator sets. In systems with inadequate load, a load bank should either be incorporated into the generator set and utilize the radiator cooling air flow, or be remotely installed with electric driven fans. Automatic controls are available that automatically disconnect the test load during actual power emergencies.

NFPA 99, Standard for Health Care Facilities, 1996 has similar requirements and would be applicable for these facilities.

Independent Testing

The InterNational Electrical Association (NETA) and its members provide the option for independent third party testing. A NETA firm is corporately independent. A NETA firm performs work in accordance with guidelines specified by the association. The firm maintains a calibration program directly traceable to the National Bureau of Standards for all instruments. The NETA firm has a Professional Electrical Engineer on staff, or under contract, to review all short circuit studies, overcurrent coordination studies, and other engineering reports.

NETA has standards for the testing of Emergency Systems, including the Engine Generator (7.22, 1), and Automatic Transfer Switches (7.22, 4). They also have standards for the testing of ground-fault protection systems, direct-current systems, batteries, switchgear, metering, transformers, circuit breakers, and other electrical equipment.

As an example, the Automatic Transfer switch tests include visual and mechanical inspection, and electrical test. These tests include checking for physical damage, and verification of interlocking. Tightness of the bolted connections is done either by calibrated torque wrench or thermographic survey. Electrical tests include insulation-resistance test phase-to-phase, and phase-to-ground. Other tests include contact-resistance test or millivolt drop test, and verification of settings and operation of control devices.

NETA firms test per ANSI, ASTM, IEEE, NEMA, NFPA, OSHA and other established standards as referenced in the Appendix.

United States Testing Co., Inc. and others provide a variety of engineering services for field testing and inspection. These firms can provide another technical resource for industry. They offer in-process and final inspections for buyers to ensure compliance with established contractual requirements. Generally they do not conduct the actual test, but perform vendor surveillance, and certify that the test have been performed, and the product meets the specification.

The Role of Factory and Distributor at Start Up:

Both the manufacture and the local distributor have a place in the successful installation, and long term reliability of all emergency power systems. Both have areas of expertise and responsibility that must be assigned. Since the local distributor is physically located near the project site, coordination issues usually are his responsibility.

While the actual interconnections and equipment installation are the responsibility of the installing contractor, technical support by the local distributor will ease the installation.

The local distributor is also responsible for either providing the fuel and fluids, or the coordination, of obtaining the necessary engine fluids, and fuel. Antifreeze and lubricating oils must meet the manufacturers specified requirements. The distributor will check the current transformer mounting and polarity, and the phase rotation and phasing between the generator set, switchgear, and loads (particularly motors). He will run the engine generator set(s) making sure they are producing rated voltage, and frequency. If the installation involves existing generator sets he must complete all retrofits and modifications so that they are capable of running in parallel with the new system.

The distributor is responsible for verifying that the system installation is complete, the tanks are full, the batteries charged, and that the site is safe and ready for testing. The distributor is also responsible for providing load banks if the building load is not adequate to conduct the test.

The local distributor is also the first contact for any warranty issues, and can provide fixed price maintenance contracts for the installed equipment. Maintenance contracts can relieve the owner from the maintenance and some of the testing of the equipment. Routine bimonthly testing usually is conducted by the owner. Maintenance contracts are very effective on sites where there is a lack of trained maintenance staff. Maintenance contracts establish a close working relationship between the owner and the distributor, and can even include provisions for the supply of temporary equipment during major repairs, and overhauls. Maintenance contracts usually include periodic load bank testing to ensure complete system load capability.

Training of Operating and Service Personnel:

Training of the equipment operator in the proper and safe operation of the installed equipment is a minimum requirement. Most specifications require that a minimum of 4 to 8 hours of on site hands on training be conducted. Since emergency power systems vary in size and complexity, the minimum would only be adequate for an operator who is familiar with similar systems, and systems that include only a generator set and transfer switch.   The addition of switchgear would require additional time, and usually a review at the 6 month equipment anniversary. Training can be video taped for later reference, with the manufacturing editing for any errors.

The manufacturer usually offers factory training for both distributors, and the customers' technicians. Schools are offered at regular intervals and include modules for generators, controls, automatic transfer switches, and switchgear. The course length varies but is usually run two to three days per module. The use of quality training materials, and experienced instructors facilitate the experience.

Customers with a large installed equipment base have the option of either factory, or their own training centers. The Federal Aviation Administration has equipped their Oklahoma center with ten Kohler® Company generators, and automatic transfer switches. The FAA will conduct fifty-five four week courses during the next four years, as a part of the FAA’s National Engine Generator Set Replacement program. During the training there will be both classroom and “hands on” training.

Operating and Maintenance Manuals:

Operation and maintenance manuals vary in both content and quality. Good documentation permits the safe installation, effective operation, and trouble shooting of all on site equipment by technically competent personnel. One set of technical manuals should be supplied and arrive with the equipment. Additional copies, the quantity as specified, should be shipped to the designated parties.

Manuals should be indexed. Materials should include at Table of Contents for easy access to the materials. A system overview with all job references, order numbers, electrical system data, and complete generator data including optional accessories is also required.

Preparation, Installation, and Notes should include instructions for equipment inspection at the time of delivery, proper handling, including moving and lifting, unpacking, proper storage, installation of bus and power connections, and interconnection wiring instructions..

An introduction should include a complete description and purpose for each indicator light, control switch, meter, and device. The operating sequence should describe in detail each mode of operation, the position of all control devices, and all fault conditions.

Bills of material should adequately describe the components used for easy identification and should include TAG name, manufacturers' part number, description and quantity. Wiring diagrams and drawings including outline, sectional details, sill plan, anchor details, single line, DC Schematic, AC Schematics, customer interconnect, circuit breaker schematics, point to point wiring diagrams, are all required.

Component manuals are required for each major device listed in the bill of material. This data provides adjustment, maintenance and repair information on major components like circuit breakers, synchronizers, and protective relays.

The PLC section should include a list of user changeable PLC setpoints, and identify the register name or number, factory preset value, and range of adjustment. A list of all internal PLC coils and relays and function, and a copy of the PLC program on a computer disc to permit review is required.

Appendix:

American National Standards Institute, (ANSI)

> C84.1, Electric Power Systems & Equipment, Voltage Ratings
> C37.90, Relay & Relay Systems Associated with Electrical Power apparatus

Electric Generating Systems Association, (EGSA)

> ISO 8528, Part 6, Test Methods, EGSA #36

InterNational Electrical Testing Association, Inc. (NETA)

> NETA Acceptance Testing Specification for Electrical Power Distribution Equipment and Systems
> NETA Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems

International Organization for Standardization (ISO)

> ANSI/ASQC Q90-Q94, 9000-9004 Series
> 3046, Reciprocating Internal Combustion Engines, Performance

Institute of Electrical and Electronic Engineers, Inc., (IEEE)

Std. 115-1991 IEEE Guide -- Test Procedures for Synchronous Machines
Std. C37.20-1993, Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
Std 446-1995, Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications

Kohler® Power Systems -- Technical Information Bulletin (TIB)

101, 5/95, Generator Set Rating Guidelines

MIL-STD-705, Methods of Test & Instructions, Generator Sets, Engine Driven

National Fire Protection Association, (NFPA)®

37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines, 1994
70, National Electrical Code® Handbook, 1996
99, Standard for Health Care Facilities© , 1996
110, Standard for Emergency and Standby Power Systems© 1996

National Electrical Manufacturers Association, (NEMA)

MG1-1995, Motors and Generators, 22.40, 22.41, 22.43, 22.45, 16.40, 16.45, 16.47.2, 16.48.2, 16.48.5

Society of Automotive Engineers, (SAE)

SAE J1349, Engine Power Test Code, Spark Ignition and Compression Ignition, Net Power Ratings

Underwriters Laboratories, Inc.® (UL)

UL-1558 Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear, 1993.
UL-891, Dead-Front Switchboards
UL-1008, Transfer Switch Equipment
UL-2200, Stationary Engine Generator Sets, (Not released)